

**UNCOVERING THE PROPERTIES OF YOUNG NEUTRON STARS AND THEIR
SURROUNDINGS**

NASA Grant No. NAG5-9281

Annual Report #5

For Period 1 April 2004 through 31 March 2005

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January 2005

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

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The Smithsonian Astrophysical Observatory
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The subject grant provides funding through the NASA LTSA program. This five-year grant involves the study of young neutron stars, particularly those in supernova remnants.

In the fifth year of this program, the following studies have been undertaken in support of this effort:

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We completed our study of this pulsar wind nebula and its associated young neutron star, using data from a 350ks Chandra observation. The observation reveals complex structure in the nebula which we interpret as evidence for a disrupted toroidal magnetic field. We have also identified a shell of low energy X-rays that appears to arise for shock-heated ejecta. Limits on the thermal emission from the young neutron star surface place its temperature far below standard models for neutron star cooling, thus indicating either a larger number of protons in the interior than expected, or the presence of exotic matter such as pion condensates, kaon condensates, or free quarks. These results were presented in a published manuscript (Slane et al. 2004 ApJ, 616, 403) and also reported in a press release from the Chandra X-ray Center (http://chandra.harvard.edu/press/04_releases/press_121404.html).

Chandra Survey for Compact Objects in Supernova Remnants

We have completed the first portion of a program to search for young neutron stars in nearby supernova remnants. Using X-ray observations from an approved Chandra Large Project, as well as from additional approved XMM observations, we are investigating a volume-limited sample of SNRs for which there is currently no evidence of associated neutron stars. We have obtained extensive optical and IR data to complement the project. Using ratios of the optical and IR flux to the X-ray flux for detected X-ray sources, we are systematically eliminating sources which are not neutron star candidates. For the first four SNRs in the sample, we can eliminate virtually all of the detected X-ray sources, and we derive upper limits to the surface temperature of any associated neutron star that fall far below standard models for neutron star cooling. These results have been published in ApJS (Kaplan et al. 2004, ApJS, 153, 269).

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We have carried out an investigation of the pulsar wind nebula in this composite supernova remnant. Previous X-ray observations have established the non-thermal nature of the central emission, consistent with the interpretation that it is a pulsar-powered wind nebula, and identified a potential X-ray candidate for the pulsar itself. Our Chandra observations confirm the presence of this compact source and establish a slightly extended morphology that suggests we are seeing the effects of material outflows from near the wind termination shock. The compact source resides at the tip of a trail of emission that leads back to the bulk of the radio nebula, suggesting that the PWN morphology results from a combination of the pulsar motion and the passage of the reverse shock. A manuscript reporting these results is in preparation.

Infrared Emission from Pulsar Wind Nebulae

We successfully proposed for a study of infrared emission from young pulsar wind nebulae using the Spitzer Observatory. The goal is to probe the spectral region in which critical information resides regarding spectral breaks that must occur between the radio and X-ray bands. We were awarded time for all six targets requested. Observations of the Vela Pulsar have been carried out, and the data have now been received. The remaining observations will be carried out during the current calendar year.

Cas A

As part of the Chandra Very Large Project program, our collaboration carried out a 1-million second observation of Cas A. The bipolar structure of the Si-rich ejecta (NE jet and SW counterpart) is clearly evident in the new images, and their chemical similarity is confirmed by their spectra. The deep image gives no evidence for an extended pulsar wind nebula surrounding the point source. These results have been published in ApJ (Hwang et al. 2004, ApJ, 615, L117). A detailed analysis of emission from the neutron star is underway.